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**Beauty and charm production at HERA
with lifetime tag**

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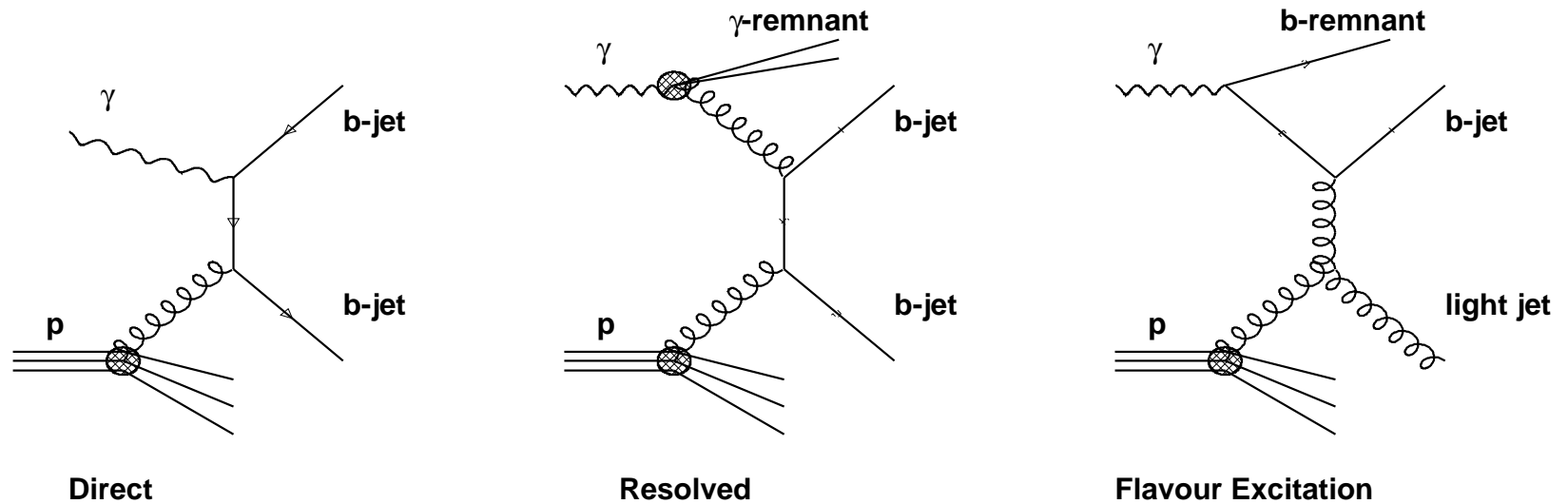


For the H1 and ZEUS
collaborations



b photoproduction in events with two jets at HERA

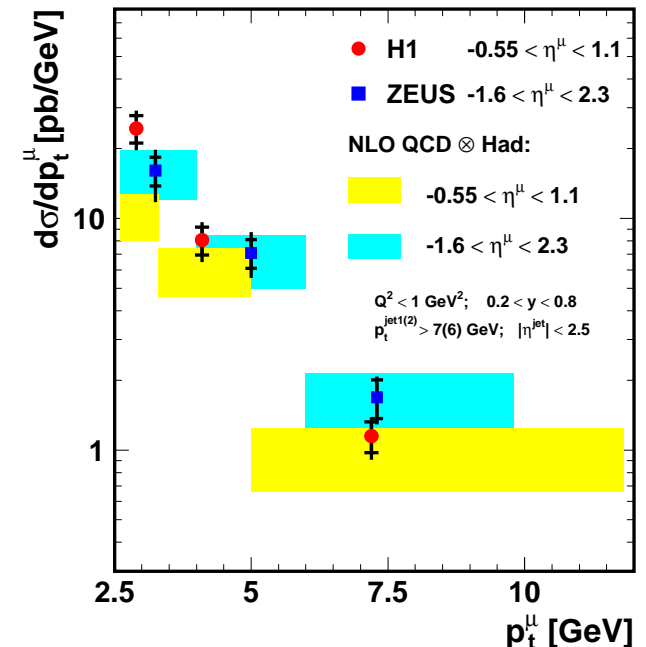
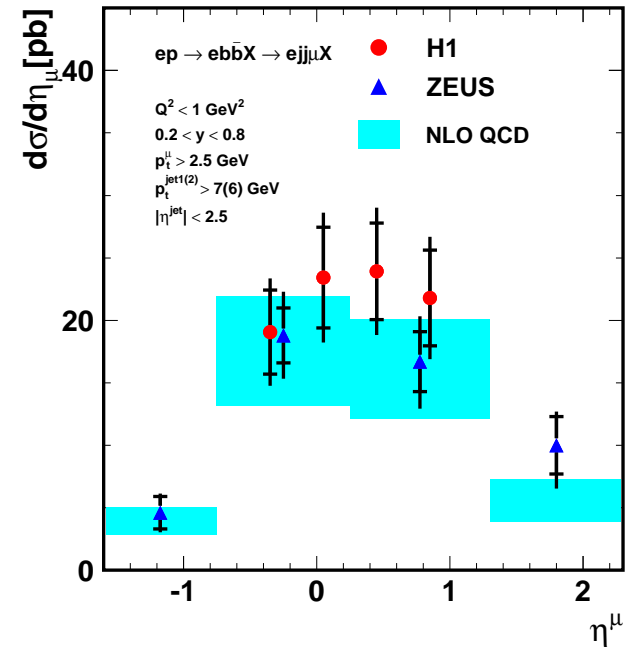
QCD is expected to make reliable predictions for b production:
 $m_b \sim 4.75$ GeV provides a large scale for perturbative calculations



- LO: Direct- + Resolved- photon diagrams
- full NLO program available (FMNR)
produces weighted events containing Q, \bar{Q} (+ g)
jets obtained by running jet algorithm on partons
correction to hadron level $O(5\%)$, taken from MC
 μ obtained by folding Q with FF (Peterson) and SL decay
- Pythia MC LO + PS, includes Flavour Excitation (FE) diagrams

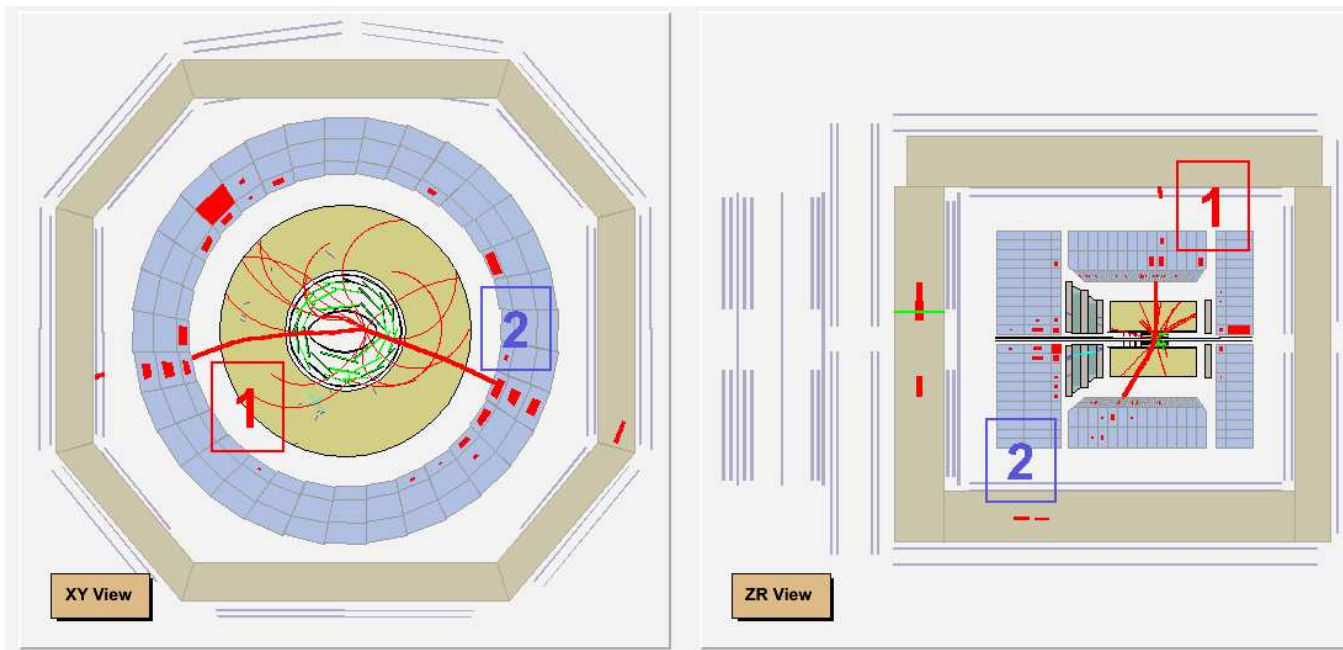
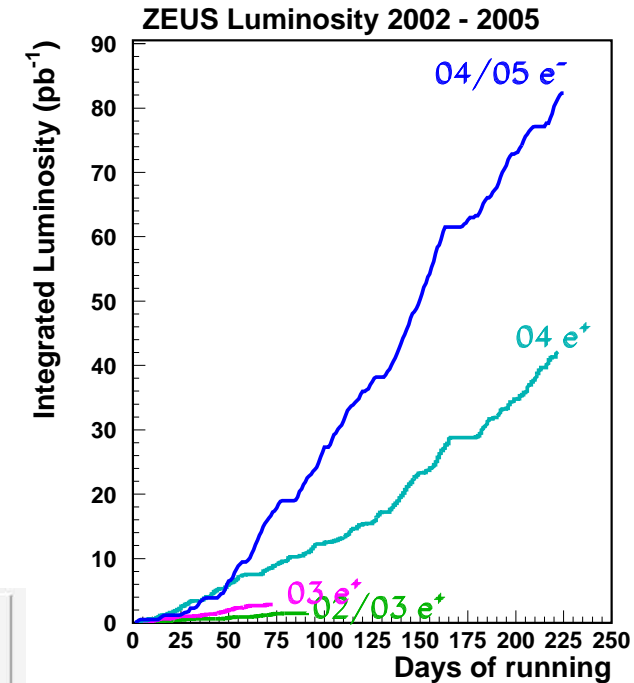
Old and new results

- $ep \rightarrow e'b\bar{b}X \rightarrow e'jj\mu X'$ measured with muons by H1 and ZEUS in HERA-I data (see talk by B. Naroska)
- Good agreement with NLO except H1 at low P_T^μ and low p_T^{jet}
- Two new results on b (and c) photoproduction associated to two jets presented here:
 - **ZEUS measurement with HERA-II data, using the microvertex detector (MVD)**
 - **H1 measurement with inclusive lifetime tag, without any muon requirement**



ZEUS measurement with HERA-II data

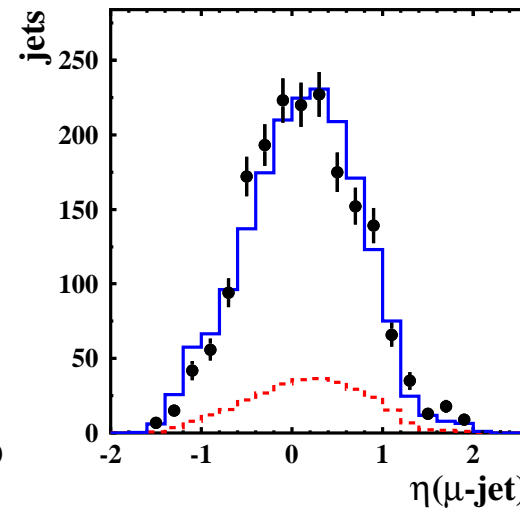
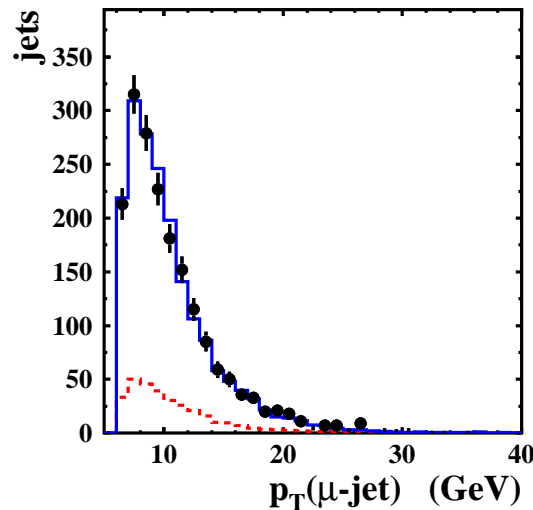
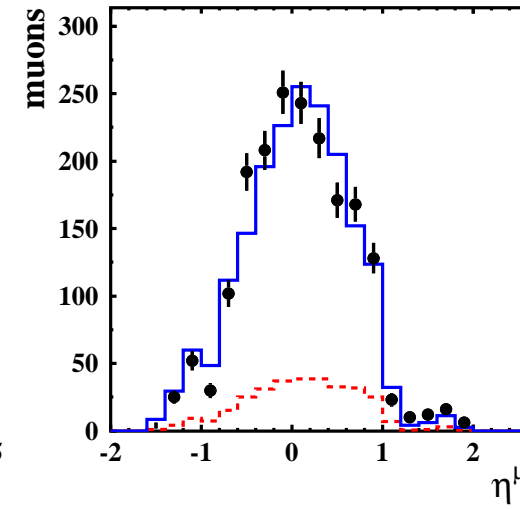
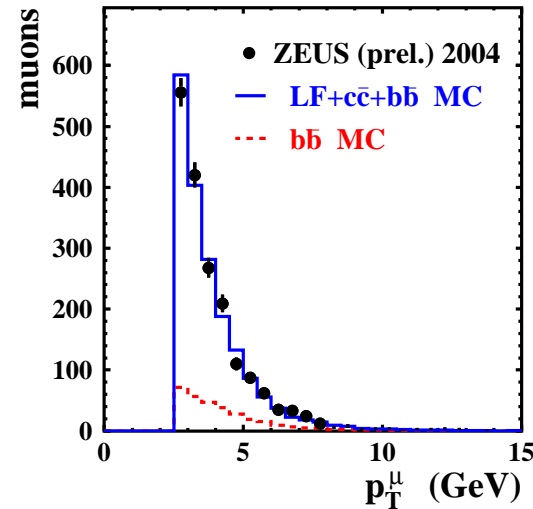
- Upgraded HERA-II, large Lumi:
ZEUS gated 03-04 e^+p $\mathcal{L} = 38 \text{ pb}^{-1}$
ZEUS gated 04-05 e^-p $\mathcal{L} > 82 \text{ pb}^{-1}$
- ZEUS silicon microvertex detector (MVD), taking physics from 2003
- first quantitative results from MVD shown here



The dijet-plus-muon sample

- $\mathcal{L} = 33 \text{ pb}^{-1}$ of 2004 e^+p data
- DIS removed, $0.2 < y_{\text{jb}} < 0.8$
- ≥ 2 jets with $p_T^{\text{J}_1, \text{J}_2} > 7, 6 \text{ GeV}$
 K_T algorithm on EFOs
- $\geq 1 \mu\text{on}$ $p_T^\mu > 2.5 \text{ GeV}$
segment in Rear/Barrel/Forward
MUON chambers matched to a
central track
with ≥ 4 hits in the MVD
- μ associated to a jet by K_T algo.
- 1806 events left
- the sample contains
 μs from SL decays of b and c ,
fake μ from punch-through and
in-flight decays of π^\pm, K^\pm
- reproduced by Pythia 6.2 MC

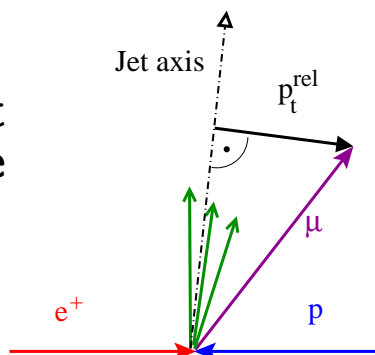
ZEUS



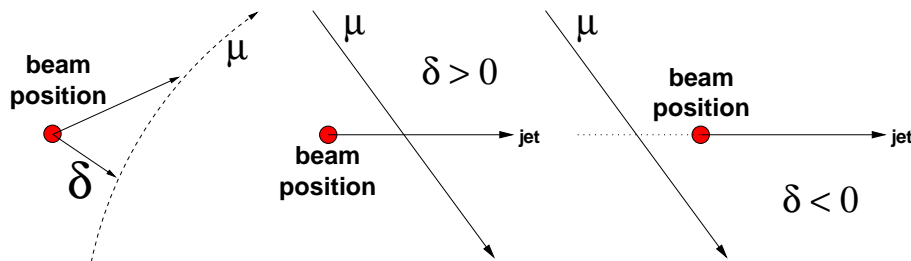
Extraction of the b and c content

- A combination of two variables is used to extract the beauty and charm content:

- p_T^{rel} : p_T of μ w.r.t. the jet axis. Large for b decays due to large b mass

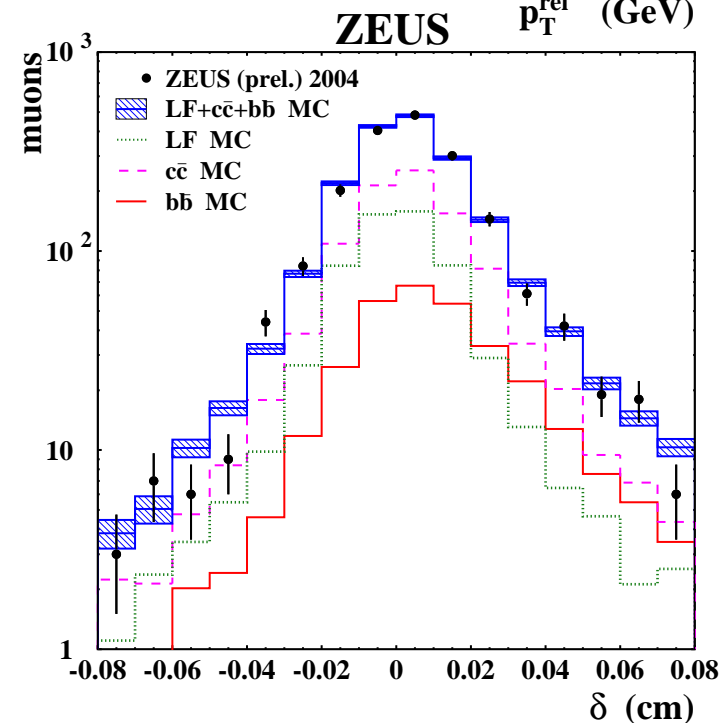
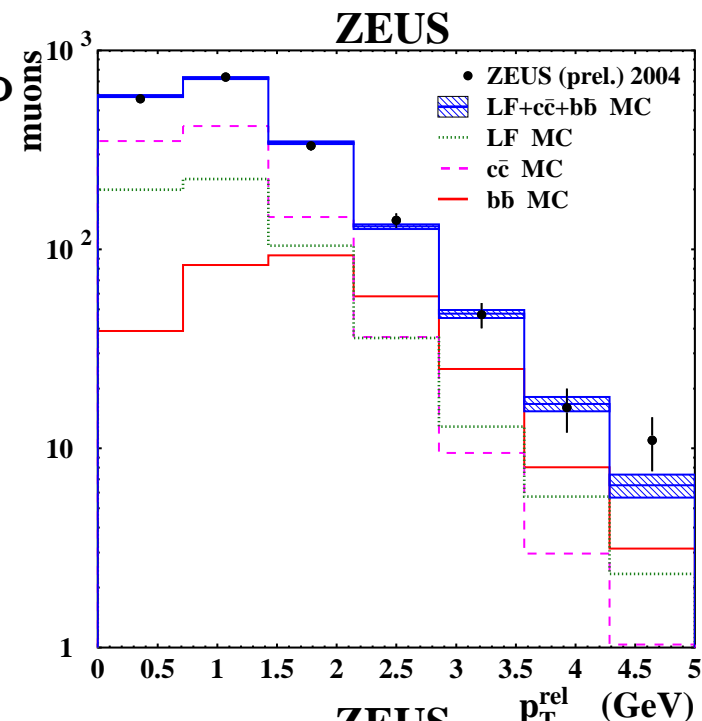


- Signed muon impact parameter δ w.r.t. beam position in X, Y
Sign defined based on the jet direction
Beam position measured run-by-run
beam size: $\sigma_X = 110\mu m$, $\sigma_Y = 30\mu m$,



Light-flavours symmetric around zero

Positive tail for b, c due to lifetime.



Combined fit of p_T^{rel} and δ

- Combined 2D fit to p_T^{rel} and δ
- Pythia 6.2 templates for b , c and light flavours (LF)

Resolution on δ in MC modeled on inclusive data

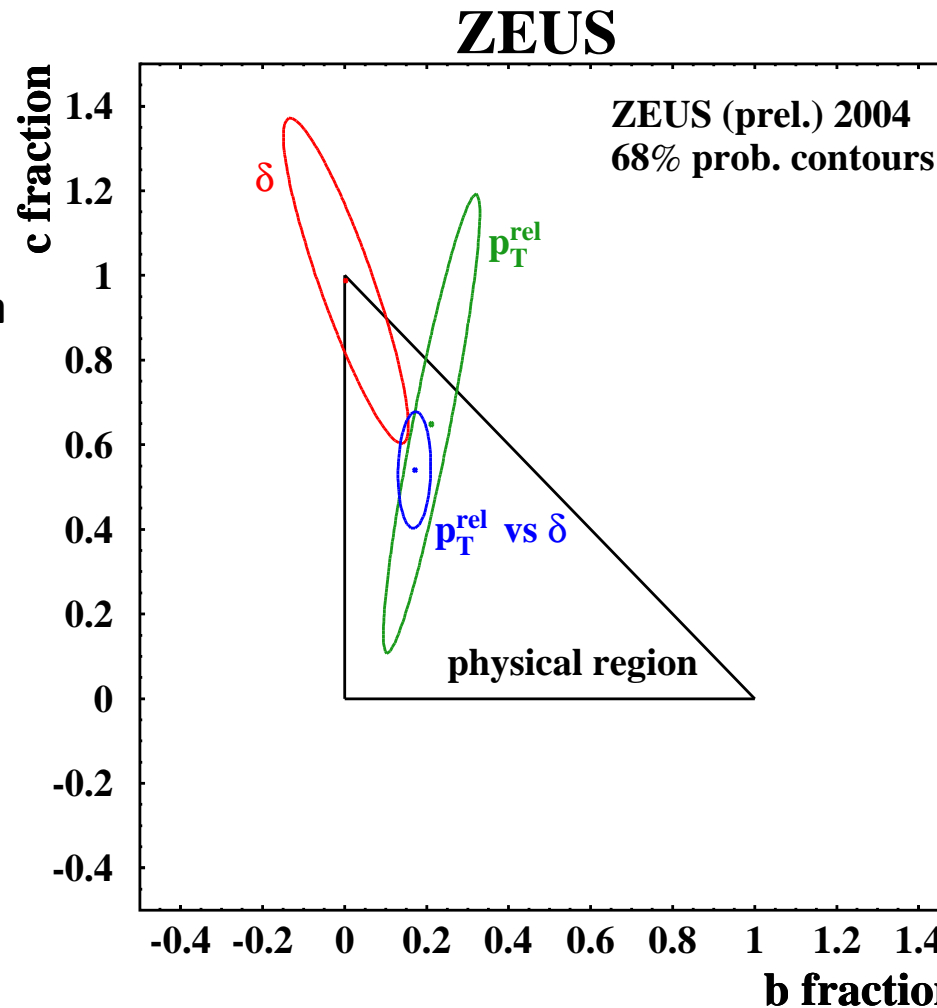
Correction of p_T^{rel} shape for LF MC based on inclusive dijet data

- Result:

$$f_b = (16.7 \pm 2.6)\% \quad f_c = (52 \pm 10)\%$$

.

- Fits of p_T^{rel} or δ alone are compatible but less precise

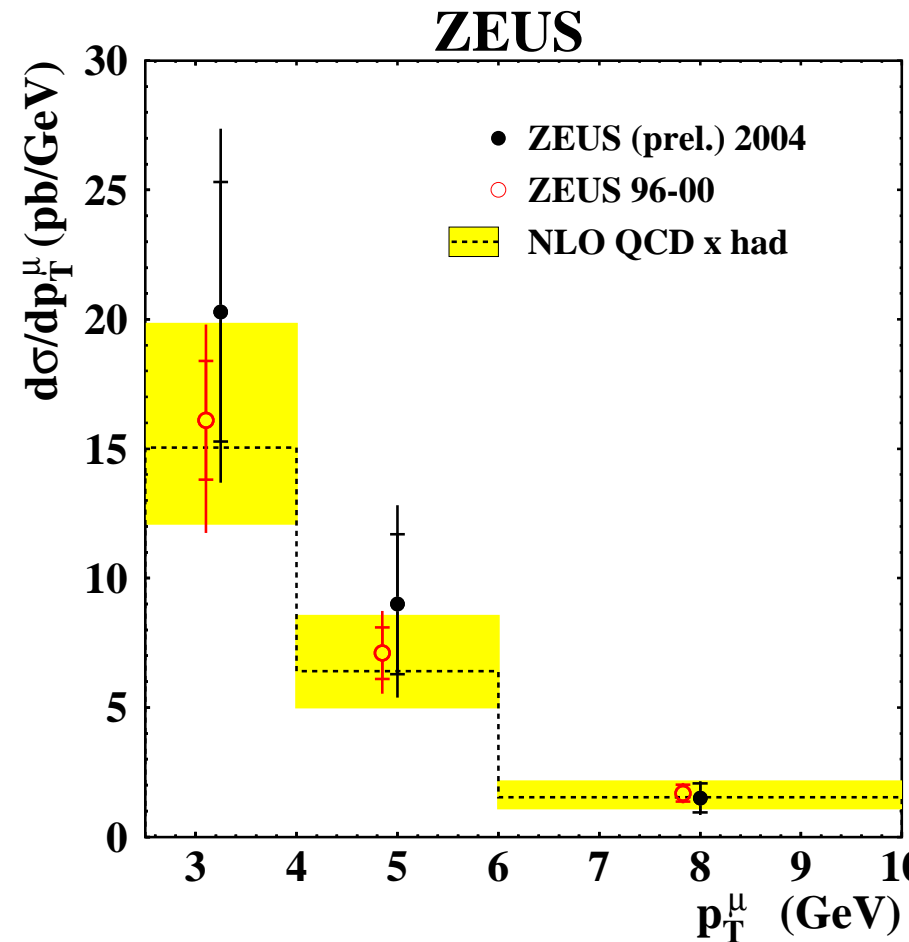


Results

- $d\sigma/dp_T^\mu$ for $ep \rightarrow e'b\bar{b}X \rightarrow e'jj\mu X'$
 $Q^2 < 1\text{GeV}^2$, $0.2 < y < 0.8$
 $p_T^{j_1, j_2} > 7, 6\text{GeV}$, $\eta^j < 2.5$
 $p_T^\mu > 2.5\text{GeV}$, $-1.6 < \eta^\mu < 2.3$
- main syst. uncertainty:
 μ chamber efficiency (15%)
 (room for future improvement)
- Agreement with NLO QCD (FMNR)
 + hadronisation corr.
- Agreement with HERA-I ZEUS data
 based on ~ 3 times larger luminosity.

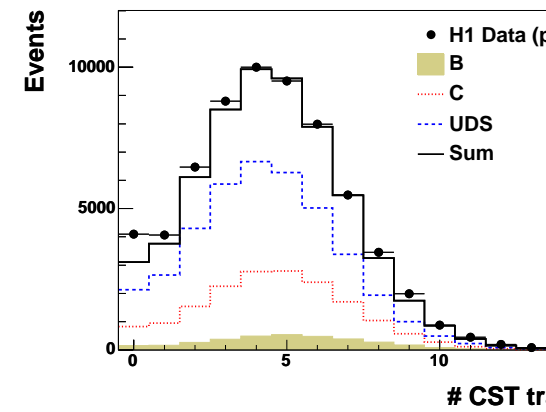
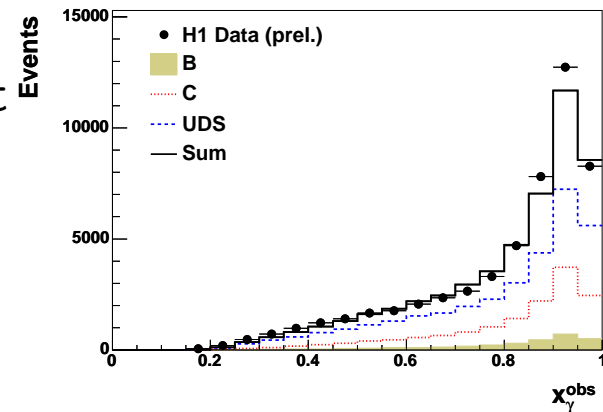
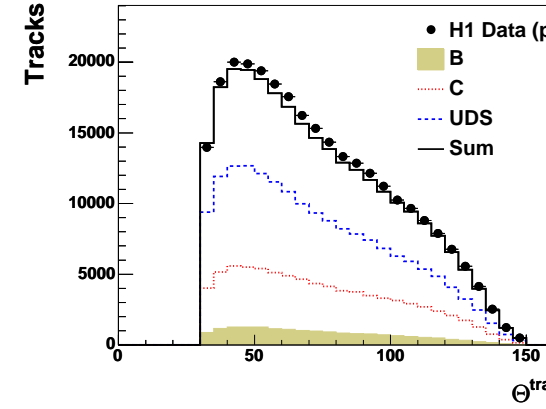
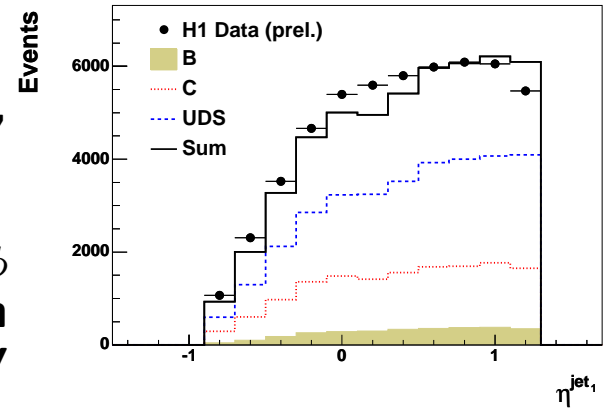
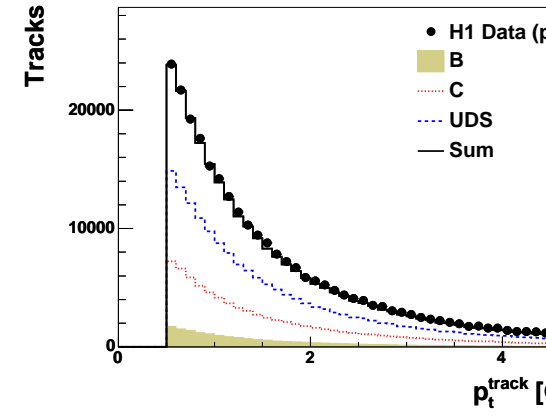
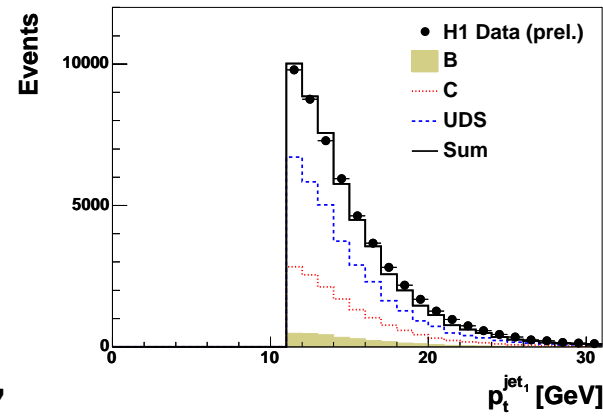
In the old measurement p_T^{rel} was used in combination with an external constraint on f_c . Here f_c is obtained from the same data.

- No hint for an excess at low p_T^μ ,
 acceptance at low p_T^μ improved w.r.t.
 prev. measurement



H1 measurement with inclusive lifetime tag

- $\mathcal{L} = 57.7\text{pb}^{-1}$ of 99-00 data
- No DIS e ($Q^2 < 1\text{GeV}^2$), $0.15 < y < 0.8$
- ≥ 2 jets with $p_T^{j_1, j_2} > 11, 8 \text{ GeV}$, $-0.88 < \eta^j < 1.3$
- ≥ 1 central tracks with $r - \phi$ hits in the central silicon tracker (CST), $p_T > 0.5\text{GeV}$ and $30^\circ < \Theta < 150^\circ$
- jet-track association by cut on ΔR in $\eta\phi$



Inclusive track impact parameter

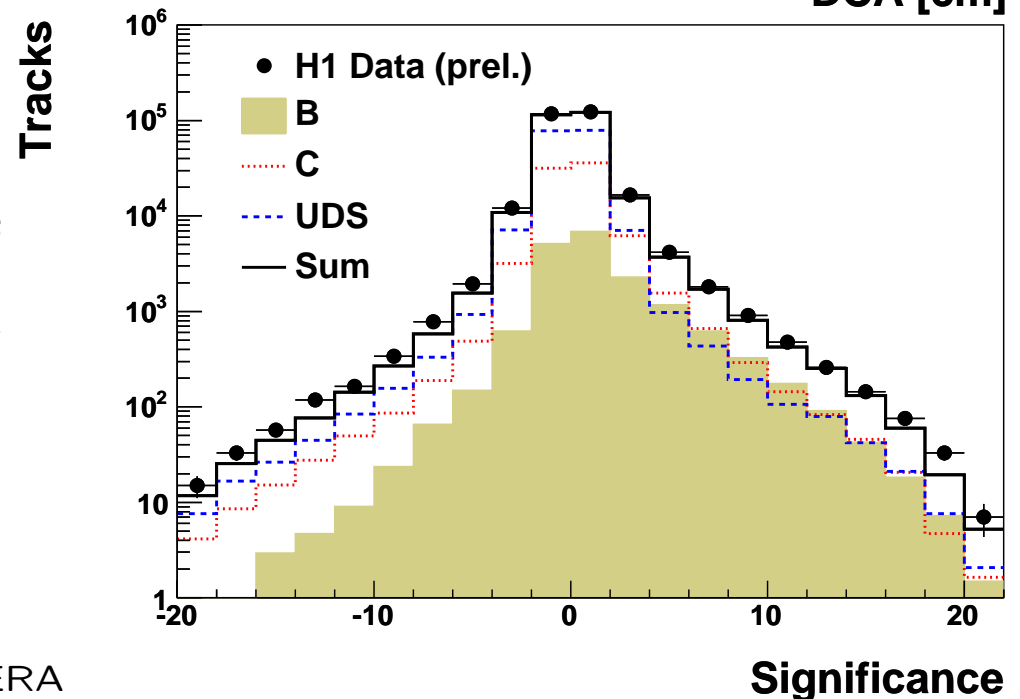
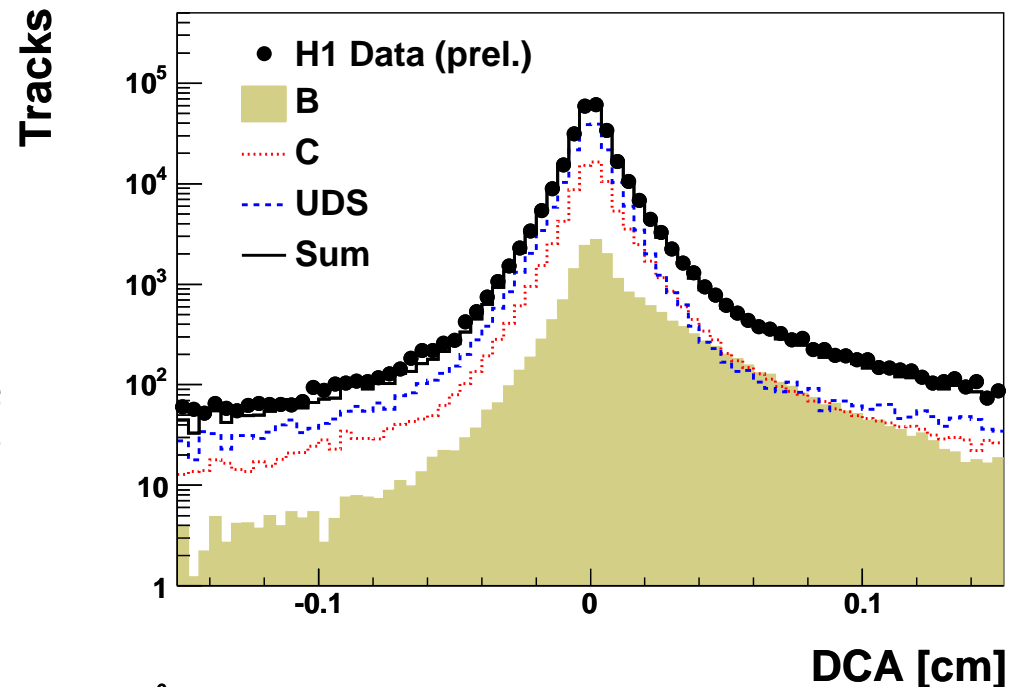
- Impact parameter defined as the DCA of the track w.r.t. the beam position in X, Y

Beam position measured with $5\mu m$ accuracy, beam size:

$$\sigma_X = 145\mu m, \sigma_Y = 25\mu m$$

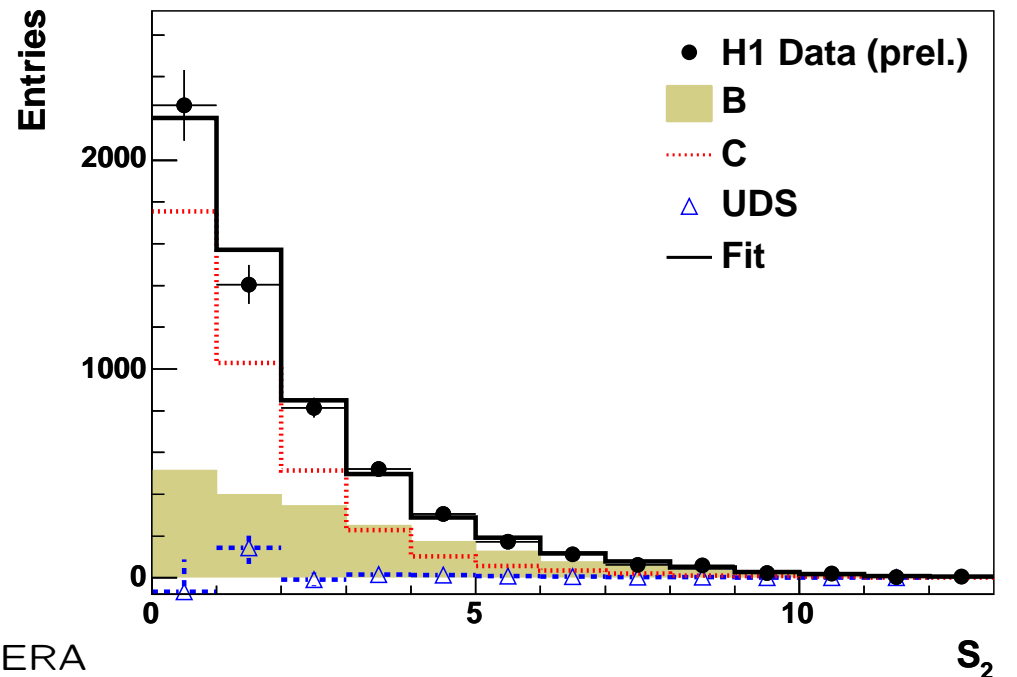
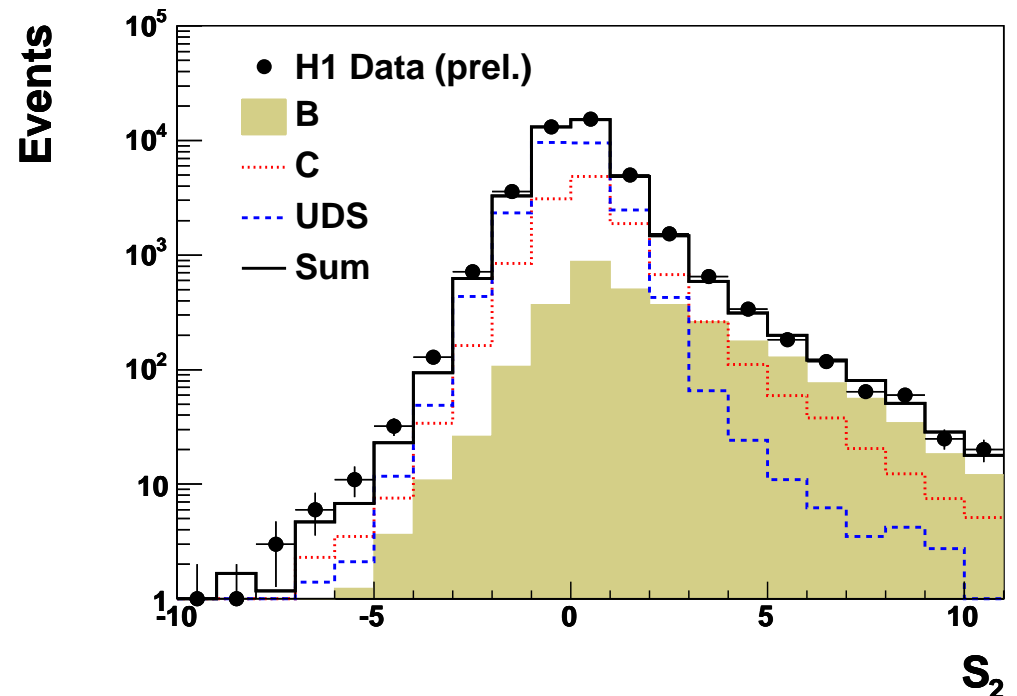
Sign defined w.r.t associated jet

- Impact Parameter significance
 $S = DCA/\sigma_{DCA}$
 use only tracks with $|DCA| < 1mm$



Extraction of beauty and charm content

- Significance of second-highest significance track S_2 used to extract b and c content. If only 1 track, S_1 is used instead $S_1 S_2 > 0$
- To reduce dependence from tracking resolution
negative S mirrored and subtracted from positive
- χ^2 fit with fixed normalisation
Templates for b , c , LF taken from Pythia MC



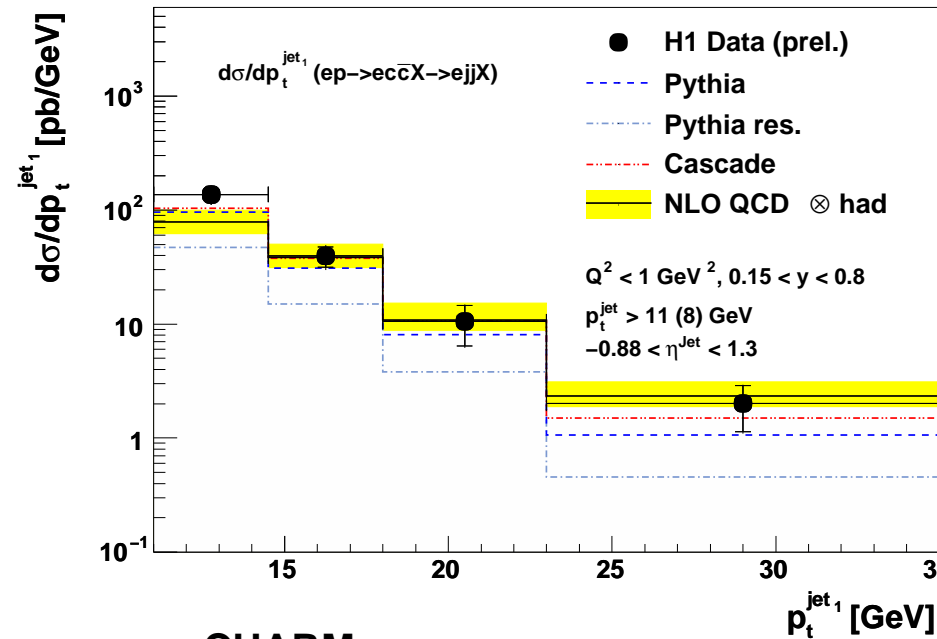
Charm cross sections

- Cross sections for
 $ep \rightarrow e'c\bar{c}X \rightarrow e'jjX'$
 $Q^2 < 1 \text{ GeV}^2$, $0.15 < y < 0.8$,
 ≥ 2 jets, $p_T^{j_1, j_2} > 11, 8 \text{ GeV}$,
 $-0.88 < \eta^j < 1.3$:

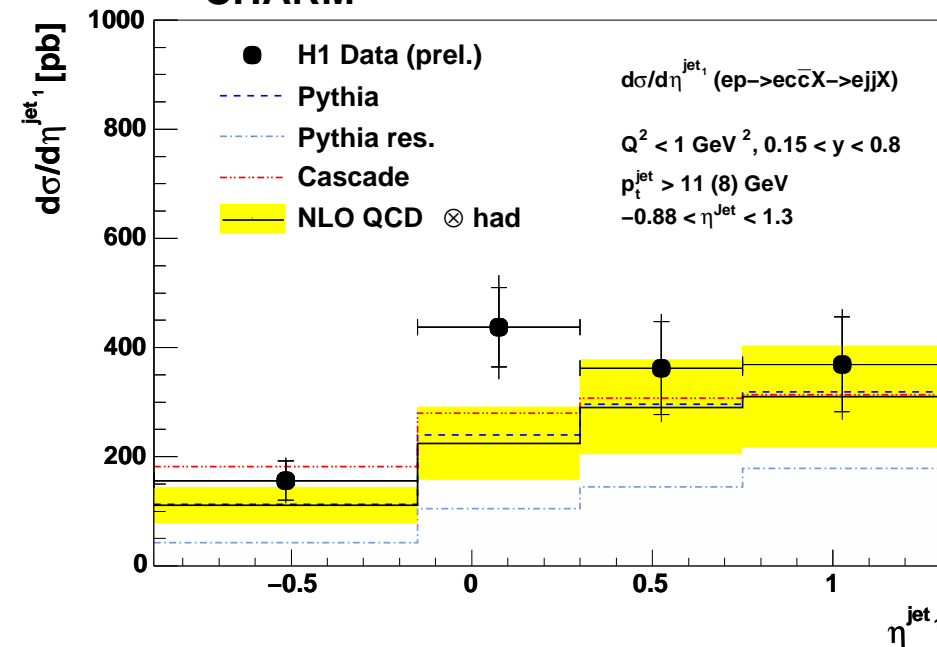
$$\sigma(c\bar{c}) = 694 \pm 69(\text{stat.}) \pm 96(\text{syst.}) \text{ pb.}$$

- Good agreement with NLO QCD (FMNR) with hadronisation corr.
- QCD uncertainty band:
 $1.3 < m_c < 1.5 \text{ GeV}$
 $\mu_F = 2\mu_R = (0.5 \dots 2) \sqrt{m_c^2 + p_T^2}$

CHARM



CHARM



Beauty cross sections

- Cross sections for

$$ep \rightarrow e' b \bar{b} X \rightarrow e' j j X'$$

$$\sigma(b\bar{b}) = 145 \pm 18(\text{stat.}) \pm 30(\text{syst.}) \text{ pb.}$$

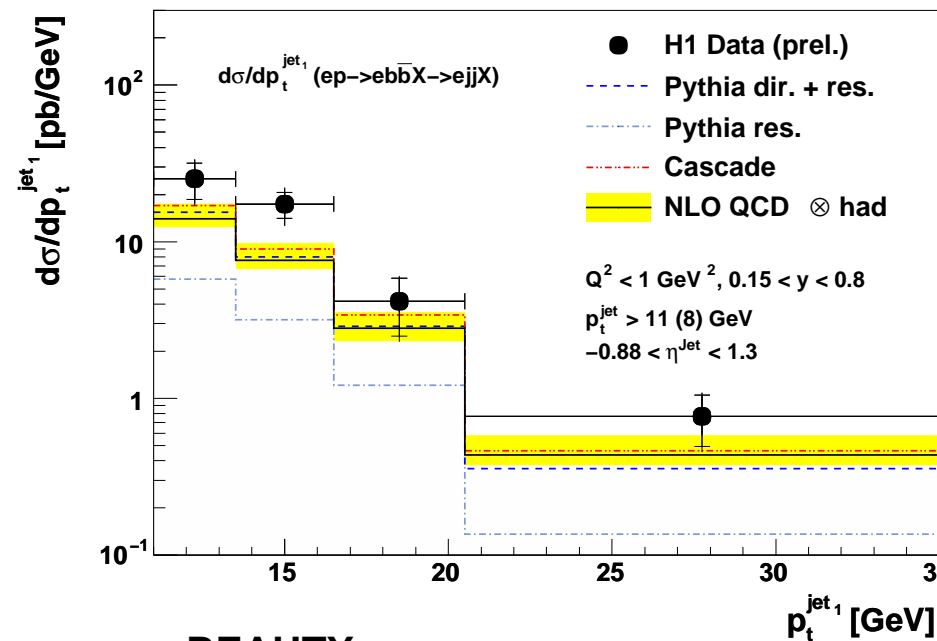
- 1-2 sigma above NLO-QCD at low $p_T^{j_1}$, large η^{j_1} regions where resolved-photon contribution is large...

- QCD uncertainty band:

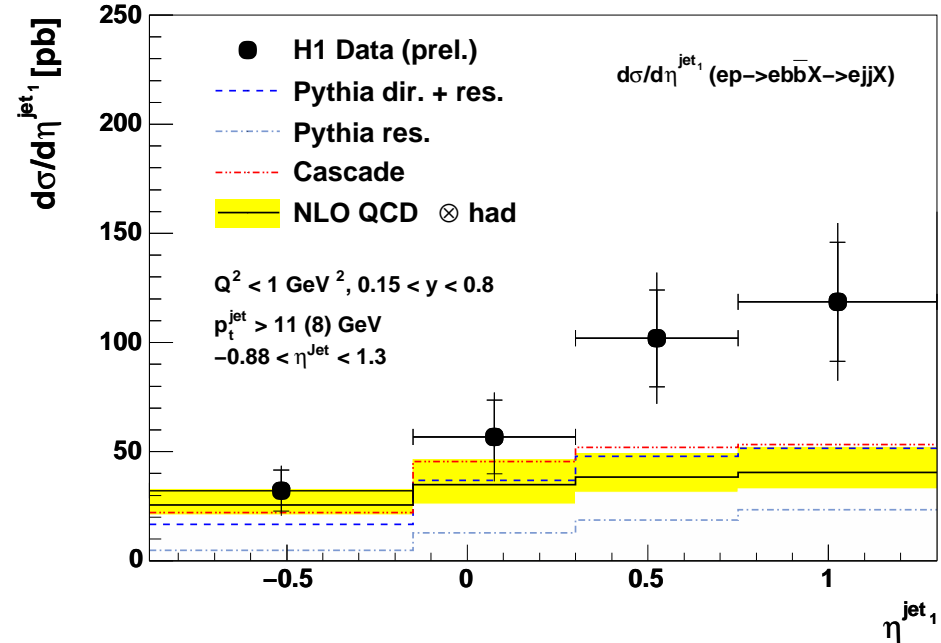
$$4.5 < m_b < 5 \text{ GeV}$$

$$\mu_F = \mu_R = (0.5 \dots 2) \sqrt{m_b^2 + p_T^2}$$

BEAUTY



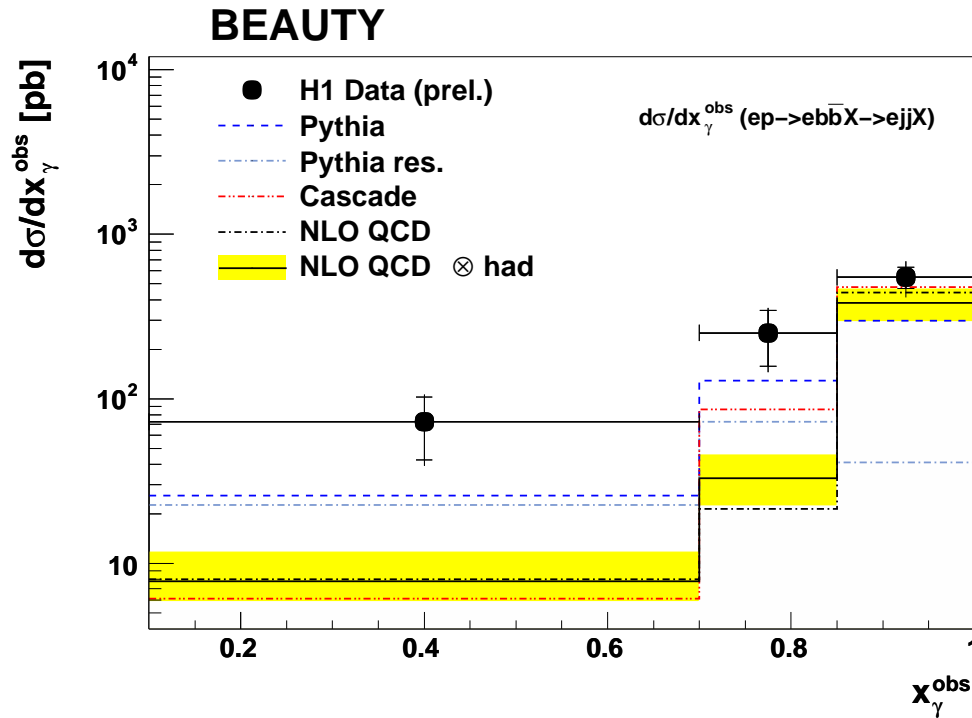
BEAUTY



x_γ^{obs} distributions

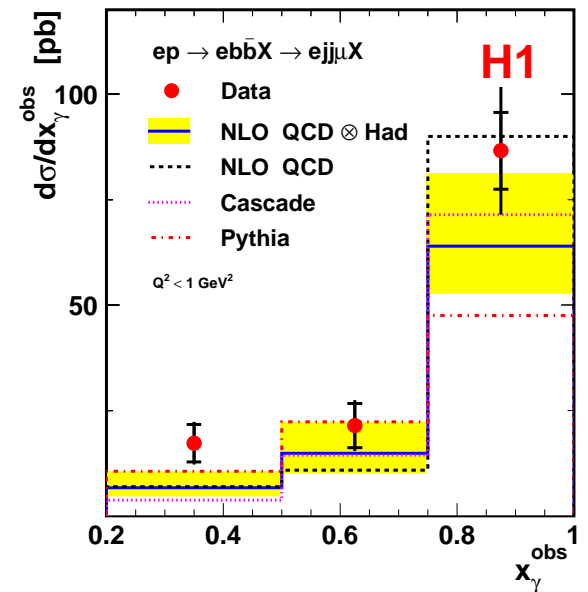
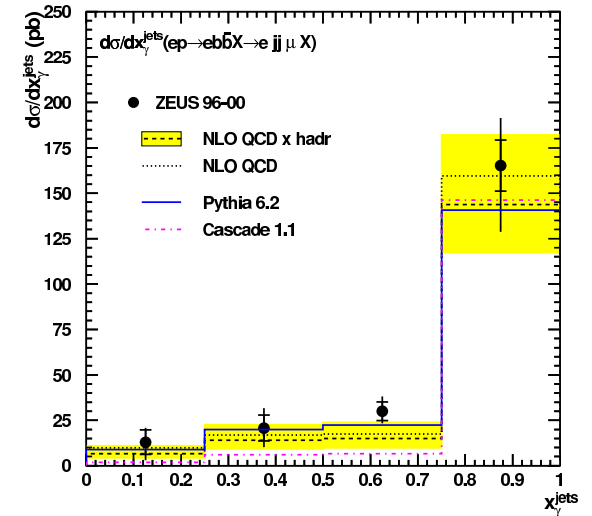
- x_γ^{obs} sensitive to direct and resolved:

$$x_\gamma^{\text{obs}} = \frac{\sum_{j_1, j_2} (E - P_z)_j}{(E - P_z)_{\text{tot}}} \quad \begin{array}{l} x_\gamma^{\text{obs}} \sim 1: \text{ direct LO process} \\ x_\gamma^{\text{obs}} < 1: \text{ resolved or higher orders} \end{array}$$



- Data higher than NLO for $x_\gamma^{\text{obs}} \leq 0.85$ anyway low significance, large hadr. corrections
- Measurement with muons (at lower p_T^{jet}) in agreement with NLO \Rightarrow

ZEUS



Conclusions

- Two new measurements of beauty (and charm) photoproduction in dijet event

- First b results from HERA-II;

the use of the ZEUS MVD improves the determination of b and c content;

good potential, large improvement over HERA-I data expected with full HERA-II luminosity and further understanding of the detector.

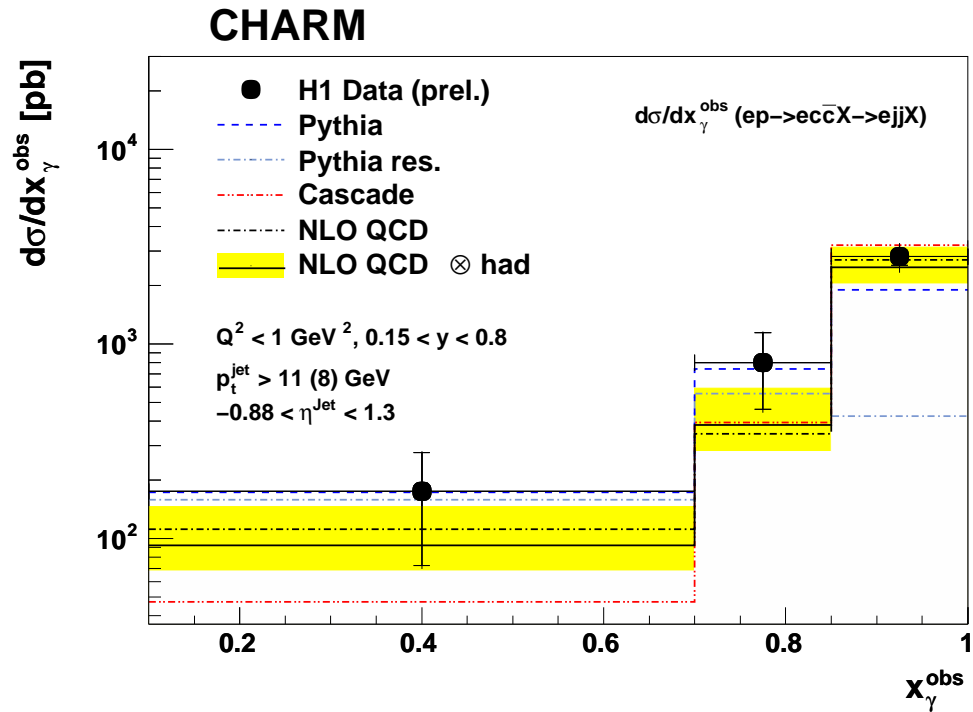
- H1 measurement based on inclusive lifetime tagging (without lepton tag);

method largely independent from those of previous measurements.

- Both results in agreement with previous measurements and NLO QCD.

Backup Slides

x_γ for Charm



p_T^{jet} for beauty in previous data

